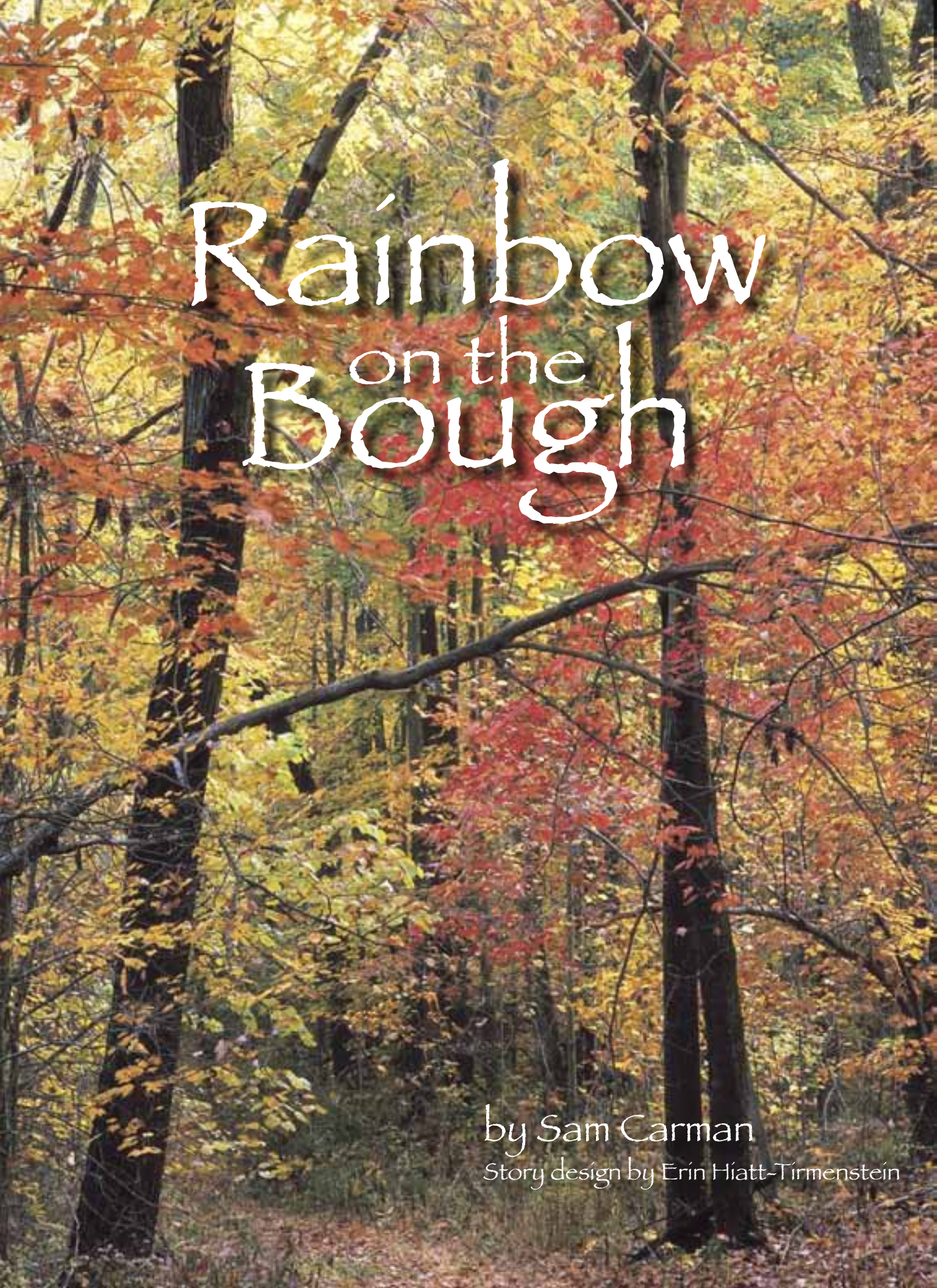

Rainbow
on the
Bough
by Sam Carman
Story design by Erin Hiatt-Tirmenstein

Richard Fields

Richard Fields

John Maxwell

One of my rules to live by is never pass up an opportunity to watch a rainbow. After all, how many rainbows is a person likely to see in a lifetime?

The science of rainbows has long been explained, but that makes them no less beautiful.

However, not all of Mother Nature's artistry is so clearly understood. As we anxiously await another Indiana autumn and the colors of the fall, scientists are still at work trying to unravel the mysteries. At least some aspects can be explained.

To best appreciate the process of fall color formation, it is helpful to understand one of the functions of a tree's leaves. During the winter, tree twigs form buds that will open in the spring to become its leaves.

The green pigment "chlorophyll" is produced inside each leaf that, along with some enzymes, allows the leaf to produce food for the tree.

The leaf uses energy from the sun and combines carbon dioxide from the air with water absorbed by its roots to produce glucose, a simple sugar. This process is called photosynthesis.

The glucose provides the tree nutrition for growth. What the tree does not use will travel to its roots for winter storage. This stored glucose eventually returns to the twigs the following spring to support the growth and development of new buds.

During the spring and summer, chlorophyll is the dominant pigment produced — but not the only pigment.

Carotenoids, which are yellow and orange in color, are also produced. Because chlorophyll is darker and much more abundant, the carotenoids are not visible during the tree's growing season.

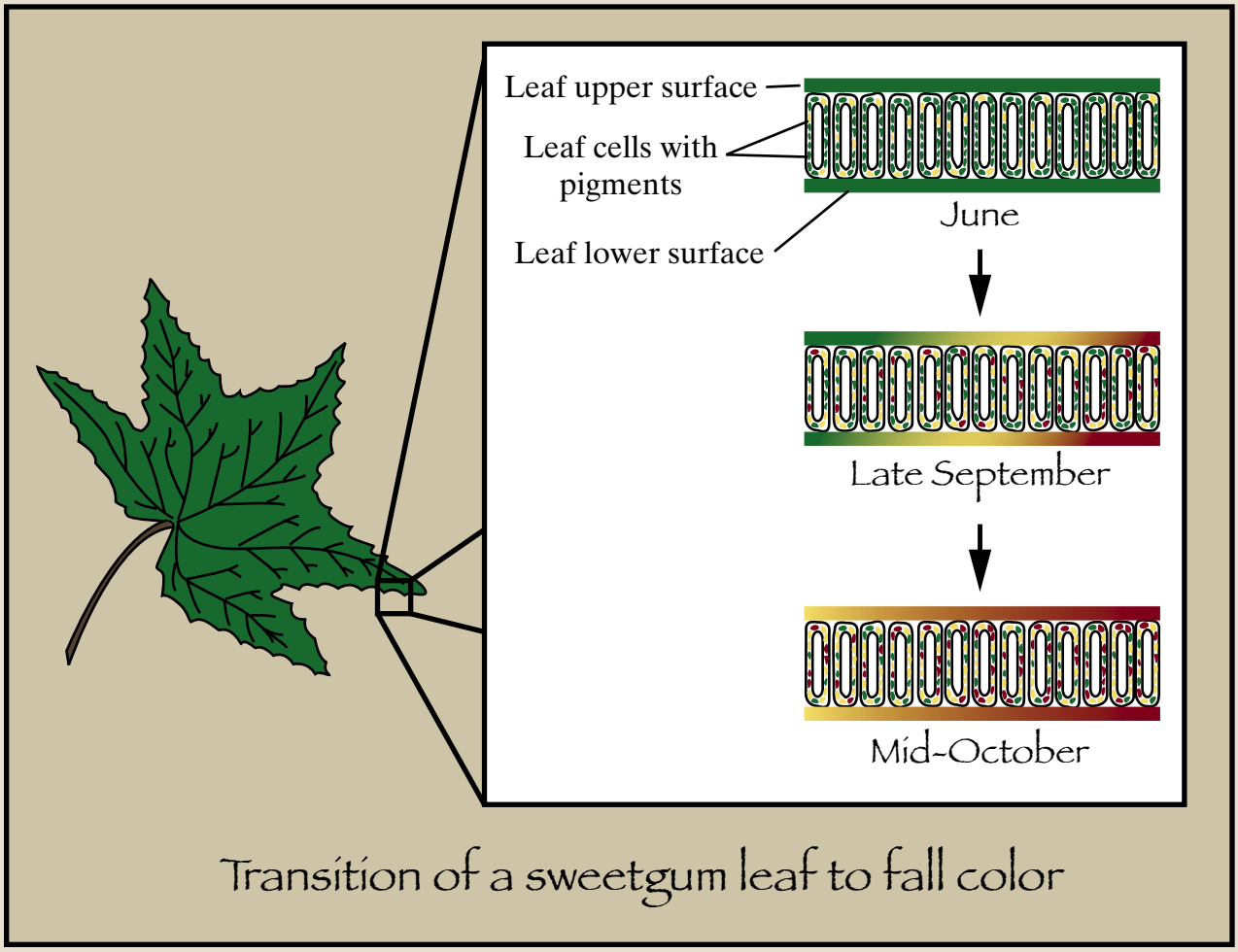
The tree begins producing less chlorophyll when autumn approaches and days grow shorter. As the amount of chlorophyll dwindles, the yellow or orange of the carotenoids becomes visible.

At the same time, another group of pigments, the anthocyanins, also develops in some trees and results in shades of red and purple.

If the tree's sap — in which the anthocyanin is dissolved — is acidic, the color will be red. Alkaline sap results in leaves displaying blue or purple hues. Some trees, oaks in particular, produce a waste product called tannin. High concentrations of tannin create leaves of brown.

Richard Fields

Fall color along a service road at Owen-Putnam State Forest includes red maple, sugar maple, tulip tree, and sassafras (left). Sugar maple leaves create a yellow carpet beside a split rail fence at Brown County State Park (above left). Dogwood leaves begin their transition from green to red as anthocyanin replaces chlorophyll in the leaves (top right). Girl plays with fallen leaves along the Whitewater Canal in Metamora (bottom right).



Erin Hiatt-Tirmenstein

The tranquil appearance of an autumn leaf is deceiving, for beneath the surface lies a hotbed of chemical activity. Molecules of chlorophyll are being dismantled and their component elements absorbed by the tree to ensure its survival and growth in the spring.

More than half of the leaf's potassium, phosphorus and nitrogen, along with some other elements, will be returned to the tree. Energy is required for the tree to absorb these nutrients, but the tree's ability to produce energy is quickly waning because of the breakdown of chlorophyll.

Without the chlorophyll, leaves can no longer carry out photosynthesis at a rate necessary to both transfer freed nutrients and maintain healthy leaves. For the tree's long-term good, most of the energy is used for the nutrient transfer. The leaves have served their purpose and will continue to deteriorate.

In addition to less chlorophyll being produced (because of shorter days) and existing chlorophyll being torn apart, another process is at work that will eventually cut off the leaf's supply of water.

At the base of the leaf's stem lies a layer of cells called the "abscission" layer. While a tree's leaves are green and active, microscopic tubes carry water from the tree to the leaves, passing through the abscission layer.

As days become shorter and temperatures cooler, cells in the abscission layer become swollen and tough. This process essentially stops the flow of water to the leaves and weakens the connection between the leaf stem and twig.

When considering the effect of weather on fall color development, two dimensions must be taken into account: fall weather while the colors are appearing, and weather throughout the summer prior to fall foliage.

Once trees begin to exhibit their fall colors, many changes have already taken place in the tree in preparation for winter. The amount of yellow in the fall was determined months before and will not be affected much by changes in the weather.

The reds, however, are in the process of forming and will most definitely be affected. Bright sunlight is needed for the production of anthocyanin, so an autumn with many sunny days will generally mean a more colorful fall.

While factors such as fall temperatures, wind and precipitation may not have a direct effect on the intensity of color, it can alter how long the leaves are on display.

Ideal conditions for fall color formation are bright, sunny days and cool, crisp nights above freezing. If

As the tree absorbs its leaves' chlorophyll, the leaves begin their yearly transition from green to the rich hues of autumn (above). Fallen forest leaves rest on the Blue River in O'Bannon Woods State Park (right).

John Maxwell

Fall Leaf Colors:

AMERICAN ELM
BLACK CHERRY
TULIPTREE
BLACK LOCUST
SILVER MAPLE
REDBUD
BEECH
HICKORY
SYCAMORE
BIRCH
HAZELNUT
SUGAR MAPLE
WITCH HAZEL
SASSAFRAS
RED MAPLE
SUMAC
WHITE OAK
BLACK GUM
RED OAK
DOGWOOD
BLACK OAK

Multi-colored or Variable:

ASH
HAWTHORN
SWEETGUM

Richard Fields

Richard Fields

Leaf colors use the whole color palette, from bright yellow to deep purplish brown (chart above). Black gum leaves turn a brilliant shade of red year after year (above right). Sweetgum leaves on a branch at Spring Mill State Park display deep red hues, although the sweetgum's palette can also include oranges and yellows (top right). Abscission is a process leading to leaf fall. It creates a characteristic stem scar that is useful for winter tree identification (lower right).

temperatures dip below freezing, the abscission layer hardens faster, which weakens the connection of the leaf stem to the tree. Combine this condition with gusty winds or hard rain, and the result is fall foliage on the ground, rather than in the trees.

Heavy rain also leaches the water-soluble pigments from leaves, so leaves remaining on the tree take on a more drab appearance.

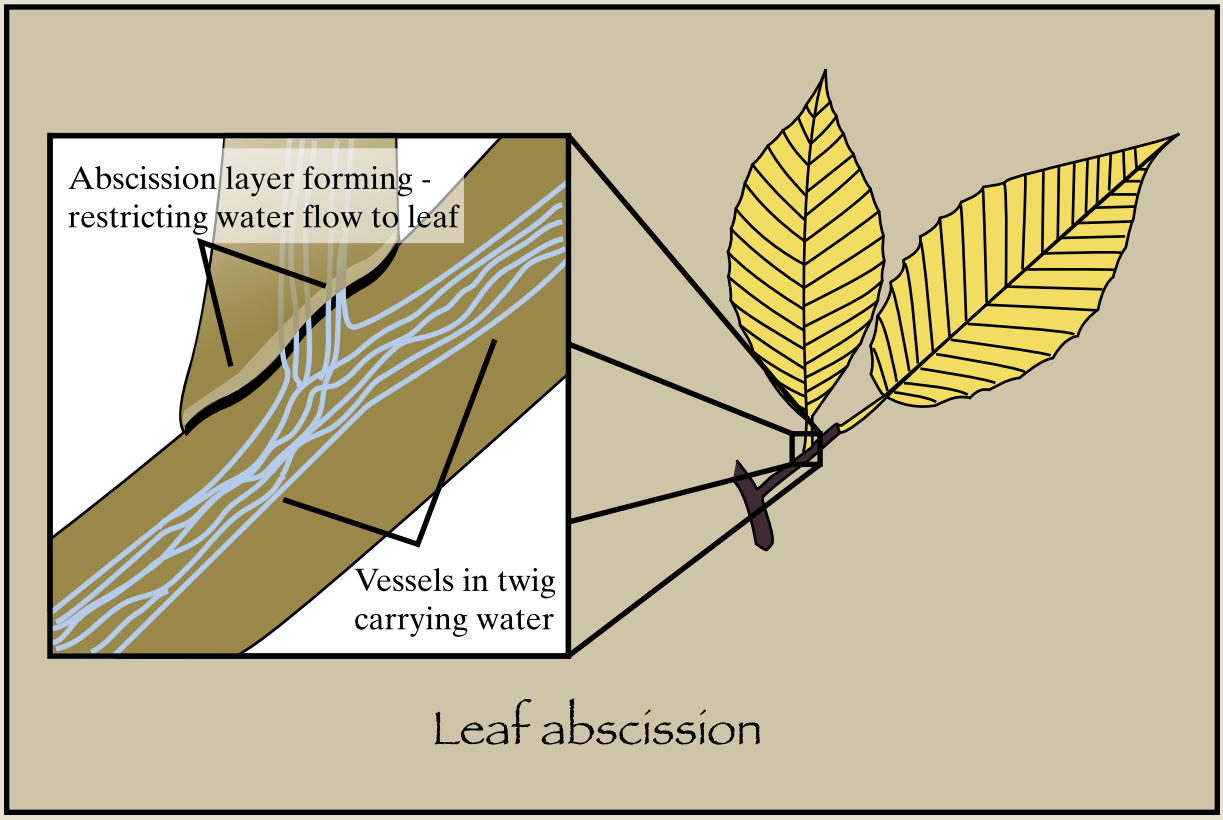
Weather throughout a tree's growing season also impacts the tree's fall colors, although this is a bit more complicated to predict.

From the time leaves break bud in the spring until late summer, they are producing chlorophyll and carotenoids. Production of these molecules can be affected most directly by rainfall, sunlight and temperature. Because there are so many possible combinations of these, it is nearly impossible to predict the outcome.

For example, even in a year of drought, isolated showers and thunderstorms often occur. Such rains are unpredictable and may repeatedly fall on the same area while leaving other nearby locations dry. This situation results in pockets of fall color that are completely different than most of the surrounding area.

While there are still some unknowns about how and when color change will occur, the real mystery is why it happens at all.

Over millions of years, natural selection has favored



Erin Hiatt-Timenstein

Richard Fields

individuals of each species that exhibited physical traits most suited for survival. Trees are no exception. They are complex organisms that have evolved to function very efficiently.

Evergreen trees have developed needle-like or scale-like leaves that have very little surface area. They are protected with a waxy coating and contain substances that act as antifreeze.

The fact that a broadleaf tree sheds its leaves in preparation for winter is not surprising. Broadleaves are thin, lack a waxy coating and are filled with liquid that would freeze during the winter.

But why does a broadleaf tree expend energy to develop new pigments in the fall of the year, just when its energy-producing capability is quickly diminishing? This question has become the subject of much scientific debate in recent years.

A number of theories have been developed to explain this illogical phenomenon.

Some believe the brightly colored leaves to be an insect deterrent. Trees have some natural capacity to repel insects using chemicals made internally. When insects are looking for a place to lay their eggs in the fall, the theory suggests that brightly colored foliage acts as a red flag to the insect.

While some research appears to substantiate this claim, other scientists are skeptical. They point to areas of the country where trees exhibit bright fall colors long after insects are gone for the season.

Another idea to explain the formation of anthocyanin (red, purple and blue pigment) has to do with protecting the leaf from the sun's rays. Since the production of chlorophyll has diminished and what there is of it is being broken down, absorbing too much sunlight could actually be damaging to leaves.

To guard against such damage and allow the leaf to continue transporting nutrients to the tree, anthocyanin is formed to act as a sunscreen. Again, some research seems to support this idea, but does not explain how trees that produce no anthocyanin are protected.

Still another theory suggests that anthocyanin is produced to somehow help a tree conserve water. In areas affected by drought, it is common to see trees take on a reddish appearance in the middle of the growing season unless they are irrigated.

When autumn arrives, these trees lose their leaves at the same time as other trees that remained green because of irrigation.

But again, what about trees that produce no anthocyanin? Many of these species turn yellow when they are under stress by drought. Is this also a water conservation measure, or simply the tree trying to close up shop for the year?

The process of natural selection, survival of the fittest, would lead us to believe there must be an explanation for why broadleaf trees don their colors for the fall. Perhaps one of these theories is correct, perhaps none of them are; perhaps the truth may be a combination of these ideas and more.

That question can be left for the scientists to debate. For the rest of us, fall color seasons are like rainbows — we never know how many more we will see. Next time you follow a rainbow, the gold you see at the end just might be hanging from a beech tree! ■

Sam Carman is education director for DNR's Division of Forestry.

American beech leaves range in color from russet (reddish brown) to bright yellow in the understory woods surrounding the Tree Trail at Salamonie Reservoir in Wabash County. Pick a direction and time of month — October is "showtime" in Indiana's woods and forests (chart opposite).

Richard Fields

Fall Color Destinations

Everyone knows about the beautiful fall colors found in Brown and Parke counties. Here are some other destinations that offer breathtaking vistas.

1. Dunes State Park:
   top of Mount Tom on Trail 4
2. Chain O' Lakes State Park:
   around Sand Lake
3. Miami State Recreation Area:
   Moswa and Blue Heron Trails
4. Ft. Harrison State Park:
   Fall Creek Trail at Delaware Lake
5. Owen-Putnam State Forest:
   between Fishcreek and
   Rattlesnake Campgrounds
6. Whitewater Memorial State Park:
   beach area or boat dock
7. Jackson-Washington State Forest:
   along Skyline Drive
8. Martin State Forest:
   forest loop by Hardwood Lake
9. Harmonie State Park:
   between Cherry Hill and Wabash
   River picnic areas